1993

LAKE AND WETLAND MONITORING PROGRAM

REPORT/SUMMARY

C. Edward Carney

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Summary

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program surveyed the water quality conditions of 30 Kansas lakes during 1993. Eight of these lakes were federal reservoirs, two were major wetlands, and the remaining 20 represented State Fishing Lakes/State Parks, and city/county lakes.

Most of the surveyed lakes appeared to be constant to degrading, over time, with regard to their assigned trophic state. Eleven lakes indicated reasonably constant trophic states since their last surveys, while 11 indicated an increased trophic state. In general, the increases in lake trophic state indicated degrading water quality conditions, but may also have been influenced by recent flood conditions. Eight lakes were surveyed in 1993 that indicated an improvement (decrease) in trophic state since their last water quality survey.

A total of 67 exceedences of the Kansas numeric water quality criteria, or Environmental Protection Agency (EPA) water quality guidelines, were documented in the surface waters of the 30 surveyed lakes. Sixty of these exceedences concerned aquatic life support criteria. Seven concerned water supply, human health, or irrigation criteria. Of the latter, four of the exceedences (all for irrigation use) did not occur in lakes that currently host those particular uses.

Atrazine was the most often detected pesticide in Kansas lakes during 1993. Twenty lakes had detectable concentrations of atrazine within their main bodies. These detections ranged in concentration from 0.32 to 4.5 ug/L. Dual was detected in seven lakes (concentration ranging from 0.26 to 1.60 ug/L), while alachlor was detected in four (concentration ranging from 0.11 to 0.19 ug/L). Ten of the 20 lakes with detectable atrazine levels exceeded available aquatic life support numeric criteria (EPA Criterion Continuous Concentration of 1.0 ug/L). One of the 20 lakes exceeded the EPA Maximum Contaminant Level (MCL) for atrazine (3.0 ug/L). Dual and alachlor detections did not exceed any of the published numeric criteria.

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INTRODUCTION

Development of the Lake and Wetland Monitoring Program

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program was established in 1975 to fulfill the requirements of the 1972 Clean Water Act (Public Law 92-500) by providing Kansas with background water quality data for water supply and recreational impoundments, by determining regional and time trends for those impoundments, and by identifying pollution control and/or assessment needs within individual lake watersheds.

Program activities originally centered around a small sampling network comprised mostly of federal lakes, with sample stations at numerous locations within each lake. In 1985, based on the results of statistical analyses, the number of stations per lake were reduced to a single station within the main body of each impoundment. This, and the elimination of parameters with limited interpretive value, allowed expansion of the lake network to its present 130 sites scattered throughout all the major drainage basins and physiographic regions of Kansas.

In 1989, KDHE initiated a Taste and Odor/Algae Bloom Technical Assistance Program for public drinking water supply lakes. This was done to assist water suppliers in identifying and controlling taste and odor problems, in finished drinking water, that result from lake ecological processes and algae blooms.

Overview of the 1993 Monitoring Activities

Staff of the KDHE Lake and Wetland Monitoring Program visited 30 Kansas lakes during 1993. Of the 30 surveyed sites, eight were large federal lakes last sampled in 1990, six were State Fishing Lakes (SFLs)/State Parks/Game Management Areas, fourteen were city/county lakes (CLs and Co. lakes, respectively), and two were major wetland/wildlife management areas (WMAs). Nineteen of the 30 lakes serve as either primary or back-up public water supplies (PWSs). One lake was new to the lake network.

Table 1 compiles some general information on the lakes surveyed during 1993. Figure 1 presents the locations of the 30 lakes and wetlands surveyed during 1993. Figure 2 presents the locations and status of all sites within the Lake and Wetland Monitoring Program. In addition to routine lake monitoring, several public lakes and private ponds were investigated as part of the Taste and Odor/Algae Bloom Technical Assistance Program.

While man-made lakes are usually termed "reservoirs", this report uses the term "lake" to define all bodies of standing water within the state.

Table 1. General Information Pertaining to Lakes Surveyed in 1993.

Lake	Basin	Authority	PWS(*)	Last Surveyed
Alma City Lake	KR	Local	*	1988
Cedar Creek Lake	MC	Local	*	new
Cheney Lake	LA	FMPR	*	1990
Council Grove Lake	NE	FMPR	*	1990
Cowley Co. SFL	LA	State		1988
El Dorado Lake	WA	FMPR	*	1990
Elk Co. SFL	VE	State		1987
Gardner City Lake	KR	Local	*	1988
Hillsdale Lake	MC	FMPR	*	1992
John Redmond Lake	NE	FMPR		1990
Lake Crawford	MC	State		1987
Lebo City Lake	MC	Local	*	1985
Madison City Lake	VE	Local	*	1988
Marais des Cygnes WMA	MC	State		1990
Marion Lake	NE	FMPR	*	1990
Marion Co. SFL	NE	State		1988
McPherson Co. SFL	SS	State		1988
Melvern Lake	MC	FMPR	*	1990
Moline City Lake #2	VE	Local	*	1987
Neosho WMA	NE	State		1990
Osage Co. SFL	MC	State		1988
Pomona Lake	MC	FMPR	*	1990
Sedan North City Lake	VE	Local		1987
Strowbridge Reservoir	MC	Local	*	1988
Thayer New City Lake	VE	Local	*	1987
Wabaunsee Co. Lake	KR	Local	*	1988
Wellington Old City Lk.	LA	Local	*	1988
Winfield City Lake	WA	Local	*	1988
Wyandotte Co. Lake	MO	Local		1988
Yates Center Lake	VE	Local	*	1992

CI = Cimarron
KR = Kansas/Lower Republican
LA = Lower Arkansas
MC = Marais des Cygnes
MO = Missouri
NE = Neosho
SO = Solomon
SS = Smoky Hill/Saline
UA = Upper Arkansas
UR = Upper Republican
VE = Verdigris
WA = Walnut

FMPR = Federal Multipurpose Reservoir

WMA = Wildlife/Game Management Area

SFL = State Fishing Lake

Figure 1. Locations of the 30 lake and wetland sites surveyed during 1993 by the KDHE Lake and Wetland Monitoring Program. The "L" symbols depict lake sites while "W" symbols depict wetlands.

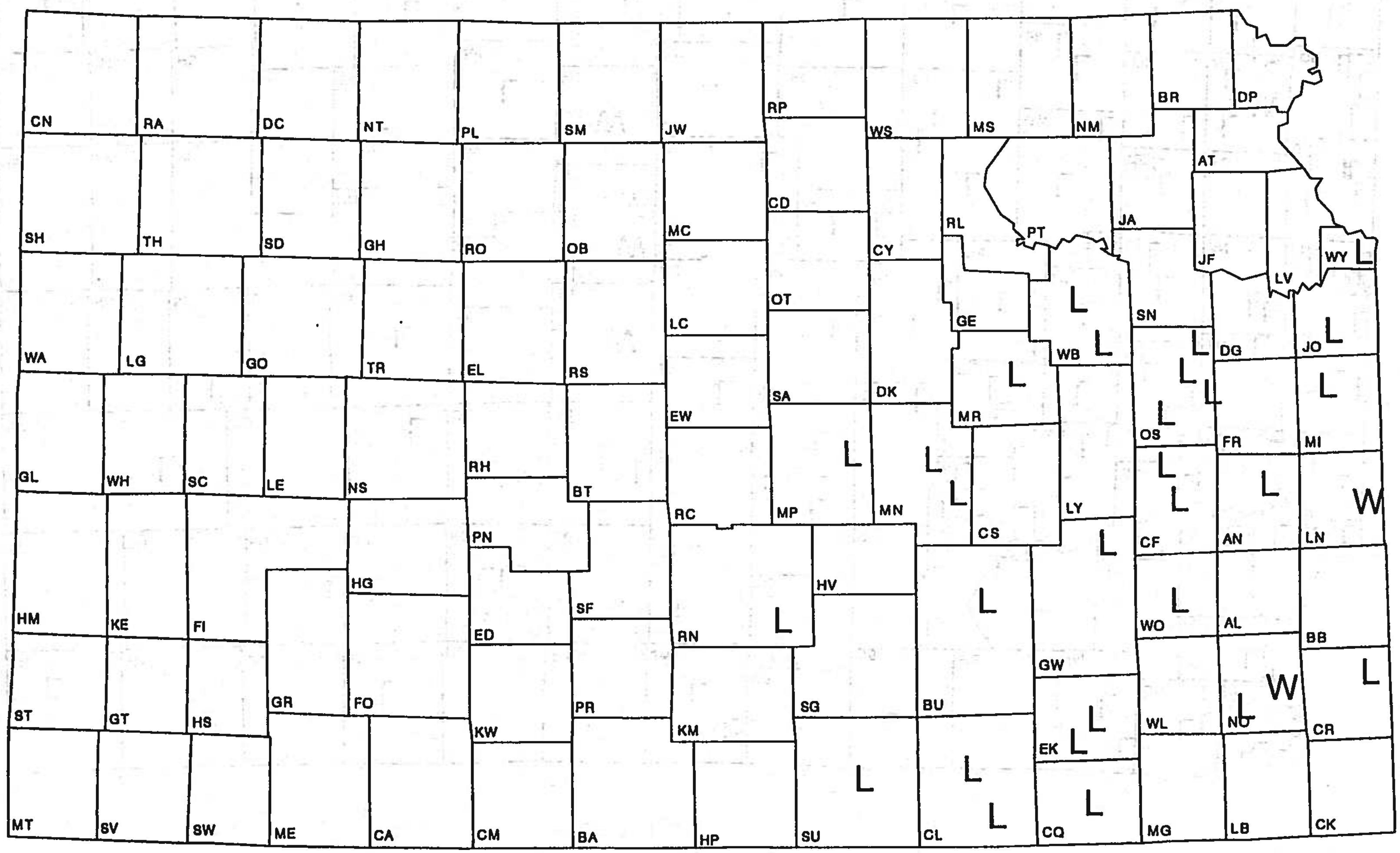
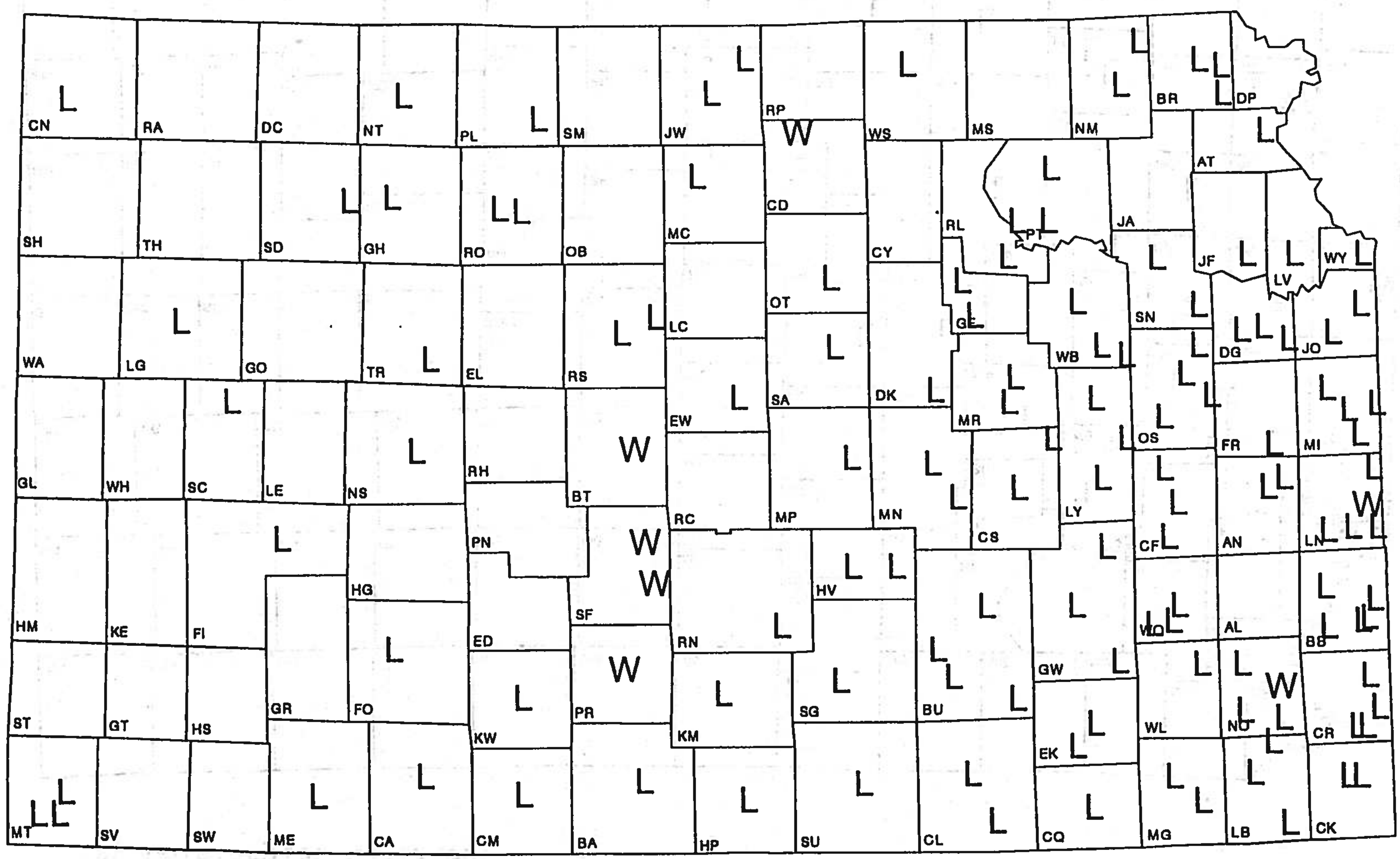


Figure 2. Locations of all lakes and wetlands within the KDHE Lake and Wetland Monitoring Program. The "L" symbols depict lake sites while the "W" symbols depict wetlands.



METHODS

Yearly Selection of Monitored Sites

Since 1985, the 24 large federal lakes in Kansas have been arbitrarily partitioned into three groups of eight. Each group is sampled once during a three year period of rotation. Up to 22 smaller lakes are sampled each year in addition to that year's block of eight federal lakes. These smaller lakes are chosen each year for sampling based on three considerations: (1) Is there recent data available (within the last 3-4 years)?; (2) Is the lake showing indications of pollution that require enhanced monitoring?; or (3) Have there been water quality assessment requests from other administrative or regulatory agencies (state, local, or federal)?

Sampling Procedures

At each lake, a boat is anchored over the inundated stream channel near the dam. This point is station 1 for each lake, and should represent the area of maximum depth. Duplicate water samples are taken by Kemmerer sample bottle at 0.5 meters below the surface for determination of inorganic chemistry (basic anions and cations), algal community composition, chlorophyll-a, nutrients (ammonia, nitrate, Kjeldahl nitrogen, and total phosphorus), and metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc). Duplicate water samples are also taken at 0.5 meters above the lake substrate for the determination of inorganic chemistry, nutrients, and metals. In addition, a single pesticide sample is taken at 0.5 meters and duplicate surface bacterial samples (fecal coliform and fecal streptococci) are taken at either the public swimming area or main boat ramp area.

Beginning with the 1992 sampling year, macrophyte surveys have been conducted at each of the smaller lakes (<400 acres) within the KDHE Lake and Wetland Monitoring Program sampling network. The survey consists of the selection of 10-20 sampling points, scattered in a regular pattern over the lake surface. At each sampling point, the boat is stopped and a grappling hook cast to rake the bottom for submersed aquatic plants. This, combined with visual observations at each station, determines presence or absence of macrophytes at the station. If present, macrophyte species are identified and recorded on site. Those species that can't be identified in the field are placed in plastic bags, on ice, for identification at the KDHE Topeka office. Presence/absence data, and species specific presence/absence data, are used to calculate a "percent bottom cover" estimate for each lake.

At each lake, measurements are made at station 1 for temperature and dissolved oxygen profiles, pH, and Secchi disk depth. All samples are preserved and stored in the field in accordance with KDHE standard operating procedure (KDHE, 1985). Field measurements, chlorophyll analysis, and algal taxonomy are conducted by staff of KDHE's Office of Science and Support. All other analyses are carried out by the KDHE Health and Environmental Laboratory (KDHE, 1984).

Taste and Odor/Algae Bloom Program

In 1989, KDHE initiated a formal Taste and Odor/Algae Bloom Technical Assistance Program. Technical assistance concerning taste and odor incidences in water supply lakes, or algae blooms in lakes and ponds, may take on varied form. Investigations may simply involve identification of algal species present within a lake, or they may entail the measurement of numerous physical, chemical, or biological parameters including watershed land use analysis to identify nonpoint pollution sources. Investigations are generally initiated at the request of treatment plant personnel, local authorities, or personnel at any KDHE District Office. While lakes used as public water supplies are the primary focus, a wide variety of samples related to algae, odors, and fishkills, from both streams and lakes, are accepted for analysis.

RESULTS AND DISCUSSION

Lake Trophic State

Calculation of the Carlson Chlorophyll-a Trophic State Index (TSI) remains a useful tool for comparison of lakes in regard to general ecological functioning and level of productivity (Carlson, 1977). Table 2 presents TSI scores for the 1993 lakes, previous TSI scores for lakes with past data, and an indication of the extent that individual lakes were dominated by submersed and floating-leaved vascular plant communities (macrophytes). Since chlorophyll TSI scores are based on the planktonic algal community, a dominance by macrophytes "bumped" the trophic state classification to the next highest level than that assigned by TSI score alone. The system used to assign trophic state, based on the TSI score, is given below. It represents an in-house modification of the Carlson TSI system to account for macrophytic productivity. Trophic state classification is adjusted for macrophytes where percent areal cover is estimated at 30% or greater.

TSI score of 0-39 = Oligo-Mesotrophic = O/M or,

O/M = A lake with a low level of planktonic algae and no large macrophyte community. In a number of Kansas lakes, this condition is related to high turbidity. In such cases, nutrient availability remains high, but is not translated into biological productivity or biomass.

TSI score of 40-49 = Mesotrophic = M or,

M = A lake with only a moderate planktonic algal community, or a small algal community combined with a large macrophyte community.

TSI score of 50-63 = Eutrophic = E or,

E = A lake with a large planktonic algal community or a moderate algal community combined with a large macrophyte community. This category is further divided as follows:

TSI = 50-54 = slightly eutrophic = SE
TSI = 55-59 = eutrophic = E
TSI = 60-63 = very eutrophic = VE.

TSI score of 64 or greater = Hypereutrophic = H or,

H = A lake with a very large planktonic algal community or a large algal community combined with a large macrophyte community.

All Carlson chlorophyll TSI scores are calculated by the following formula, where C is the phaeophytin corrected chlorophyll-a level in ug/L (Carlson, 1977):

$$TSI = 10(6-(2.04-0.68\ln(C))/\ln 2).$$

The composition of the algal community often gives a better ecological picture of a lake than relying solely on a trophic state classification. Table 3 presents both total algal cell count and percent composition of several major algal groups for the lakes surveyed in 1993. Lakes in Kansas that are nutrient enriched tend to be dominated by green or blue-green species, while those dominated by diatom communities may not be so enriched. Certain species of blue-green, diatom, or dinoflagellate algae may contribute to taste and odor problems, when present in large numbers, in lakes or streams that serve as public drinking water sources.

During 1993, flood inflows caused large impacts on resident algae communities. Relatively few lakes sampled in 1993 show the "normal" green and blue-green summertime composition typical for Kansas. In many cases, flood inflows appear to have entered and exited lakes as surface layers, causing no disruption of stratification, but "flushing" resident algae communities in the epilimnion. In a number of cases, surface waters were more turbid than hypolimnetic waters. This is opposite from what is considered normal in Kansas lakes. Because of these impacts, 1993 trophic state data should be used cautiously in deriving management decisions.

Trends in Trophic State

Trends in trophic state, among these 30 lakes, appeared to be stable to degrading over time. Table 4 presents the results of the comparison of current trophic state to past records. Among the 11 lakes maintaining stable trophic states, one is identified as "tentatively stable" because no past data exists (Cedar Creek Lake).

Of the 30 lakes surveyed in 1993, eleven indicate a degrading condition, as evidenced by increases in lake trophic state. Among these were several lakes that had experienced large influxes of flood runoff. The 1993 data may, therefore, represent the transient impacts of flooding rather than significant long-term trends.

As can be seen in Table 5, 11 of the 16 macrophyte surveys resulted in no macrophytes being found. This may mean that cover was non-existent, or it may merely indicate that macrophyte presence was so sparse as to preclude detection using the current technique. Of the five lakes with measurable macrophyte communities, the common plant species were various forms of pondweed (Potamogeton spp.), water naiad (Najas sp.), and stonewort algae (Chara and Nitella spp.). The one unusual find was that aquatic mosses existed in the very turbid Cedar Creek Lake.

Lake Stratification

Stratification is a natural process that occurs in any standing body of water, whether that waterbody is a natural lake, pond, artificial reservoir, or wetland pool (Wetzel, 1983). It occurs when sunlight (heat energy) penetrates into the water column. Due to the thermal properties of water, high levels of sunlight (combined with calm winds during the spring-to-summer months) cause layers of water to form with differing temperatures. The cooler layers remain near the bottom of the lake (hypolimnion) while the upper layers (epilimnion) develop a higher ambient temperature. The middle layers (metalimnion) display a rapid drop in temperature with depth (the thermocline), compared to conditions within the epilimnion and hypolimnion.

Table 2. Current and past TSI scores, and trophic state classifications for the 1993 lakes. The abbreviations used previously for trophic state levels (O/M, M, E, H) apply here. An asterisk appearing after the name of a lake denotes that the lake was macrophyte dominated. In such a case, the trophic state based solely on TSI score is given, followed by the macrophyte-adjusted TSI score in parentheses.

Lake	1993 TSI & Status		Previous Status
Alma City Lake	67	H	M
Cedar Creek Lake	51	SE	unknown
Cheney Lake	40	M	M
Council Grove Lake	33	O/M	E
Cowley Co. SFL	56	E	E
El Dorado Lake	45	M	M
Elk Co. SFL*	55	SE(E)	E
Gardner City Lake	66	H	E
Hillsdale Lake	61	VE	E
John Redmond Lake	51	SE	M
Lake Crawford	52	SE	E
Lebo City Lake	51	SE	E
Madison City Lake	59	E	M
Marais des Cygnes WMA*	58	E(VE)	H
Marion Lake	36	O/M	E
Marion Co. SFL	53	SE	E
McPherson Co. SFL*	41	M(SE)	H
Melvern Lake	51	SE	M
Moline City Lake #2*	41	M(SE)	M
Neosho WMA*	63	VE(H)	H
Osage Co. SFL	59	E	E
Pomona Lake	52	SE	M
Sedan North City Lake	63	VE	E
Strowbridge Reservoir	47	M	E
Thayer New City Lake	45	M	M
Wabaunsee Co. Lake	49	M	M
Wellington Old City Lake	50	E	E
Winfield City Lake	60	VE	E
Wyandotte Co. Lake	54	SE	M
Yates Center Lake	58	E	E

Table 3. Algal communities present in the 1993 lakes at the time of sampling. The value in the count column is in cells/uL. "Other", in the far right column, refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellates. A "*" next to a number indicates that the percent of total, based on a biomass consideration, would be significantly above the percent of total shown, which is based on cell numbers.

Lake	Total Count (cells/uL)	Percent Composition green	bluegreen	diatoms	other
Alma City Lake	3.15	24	0	0	*76
Cedar Creek Lake	2.84	36	44	*11	*9
Cheney Lake	1.01	63	0	37	0
Council Grove Lake	0.63	100	0	0	0
Cowley Co. SFL	21.11	6	87	7	0
El Dorado Lake	0.76	83	0	0	17
Elk Co. SFL	30.49	9	87	3	1
Gardner City Lake	19.53	78	19	<1	*2
Hillsdale Lake	2.67	44	0	*28	*28
John Redmond Lake	2.96	34	0	53	13
Lake Crawford	4.28	35	0	**57	8
Lebo City Lake	8.06	6	*86	8	0
Madison City Lake	57.27	<2	98	<1	<1
Mar. des Cyg. WMA	8.57	46	0	19	**35
Marion Lake	1.45	70	0	22	*8
Marion Co. SFL	6.24	44	0	20	36
McPherson Co. SFL	1.70	63	0	7	*29
Melvern Lake	3.34	30	57	13	0
Moline City Lake #2	2.14	59	0	*35	6
Neosho WMA	6.55	42	0	52	*6
Osage Co. SFL	3.40	61	0	2	*37
Pomona Lake	0.95	67	0	0	*33
Sedan North City L.	7.25	75	0	0	*25
Strowbridge Res.	3.59	19	53	25	*3
Thayer New City L.	1.95	32	0	0	**68
Wabaunsee Co. Lake	3.59	35	0	*58	*7
Wellington Old Lake	0.76	25	0	33	*42
Winfield City Lake	13.92	2	0	98	0
Wyandotte Co. Lake	7.18	15	44	21	*20
Yates Center Lake	30.30	<1	98	<2	0

Table 4. Trends over time for lake trophic state classification within each major river basin in Kansas.

Basin	Number of Lakes Constant	Improving	Degrading
Kansas/Lower Republican	1	0	2
Lower Arkansas	3	0	0
Marais des Cygnes	2	4	3
Missouri	0	0	1
Neosho	1	3	1
Smoky Hill/Saline	0	1	0
Verdigris	3	0	3
Walnut	1	0	1
Totals	11	8	11

Once these layers of water with differing temperatures form, they tend to remain stable and do not mix with one another. The net result is no re-oxygenation from the atmosphere within the hypolimnion, at least for the duration of the summer. In many cases, this causes hypolimnetic waters to be depleted of oxygen and unavailable for fish and other aquatic life as habitat. Stratification eventually breaks down in the fall when surface waters cool. Once epilimnetic waters cool to temperatures comparable to hypolimnetic waters, the lake will mix completely once again. The fall time of lake mixing is called "lake turnover."

Lake turnover can cause fishkills, aesthetic problems, and taste and odor problems in drinking water if the hypolimnion comprises a significant volume of the lake. This is because such a sudden mixing combines oxygen-poor, nutrient-rich hypolimnetic waters with epilimnetic waters that are lower in nutrients and richer in dissolved oxygen. This often results in explosive algae growth, lowering of overall lake dissolved oxygen levels, sudden fishkills, and often imparts objectionable odors to the lake water and tastes or odors to drinking water produced from the lake. Therefore, this lake process is important in lake management, the ability of the waterbody to support aquatic life, and the ability of the waterbody to support sport fisheries.

Presence or absence of stratification is determined by the depth profiles taken in each lake for temperature and dissolved oxygen concentration. Table 6 presents this data. Any temperature change greater than -1.0 degree Celsius per meter depth is considered evidence of strong thermal stratification (Hutchinson, 1957; Wetzel, 1983), although rates may be considerably lower during the initiation phase of stratification.

Table 5. Macrophyte community structure in 16 of the lakes surveyed during 1993. Macrophyte community in these surveys refers to submersed and floating-leaved aquatic plants, but not to the emergent shoreline community. The percent species cover is the cover estimate for each documented species (Note: due to overlap in species cover, the percentages under community composition may not equal the percent total cover.).

Lake	% Total Cover	% Species Cover and Community Composition	
Alma City Lake	0%	0%	none present
Cedar Creek Lake	5%	5%	aquatic mosses
Cowley Co. SFL	0%	0%	none present
Elk Co. SFL	50%	45%	*Ceratophyllum demersum*
		5%	*Chara globularis*
Gardner Lake	0%	0%	none present
Lebo City Lake	0%	0%	none present
Madison City Lake	0%	0%	none present
McPherson Co. SFL	50%	33%	*Potamogeton nodosus*
		17%	*Ceratophyllum demersum*
		8%	*Najas guadalupensis*
Moline City Lake #2	80%	50%	*Potamogeton pusillus*
		40%	*Chara globularis*
		10%	*Nitella flexilis*
Osage Co. SFL	0%	0%	none present
Sedan North City Lake	0%	0%	none present
Strowbridge Reservoir	0%	0%	none present
Thayer New City Lake	0%	0%	none present
Wabaunsee Co. Lake	0%	0%	none present
Wyandotte Co. Lake	0%	0%	none present
Yates Center Lake	18%	17%	*Najas guadalupensis*
		12%	*Potamogeton pusillus*

Contact Recreation and Fecal Coliform Bacterial Counts

Beginning in 1992, the Lake and Wetland Monitoring Program discontinued collecting bacterial samples from the open waters of network lakes. Past data indicates strongly that fecal coliform counts are very low in the open water of Kansas lakes. This condition is likely due to predation by protozoan organisms and the fact that limnetic environments are hostile to the survival of gut bacteria in general. In preference to open water samples, fecal bacteria counts are now made from either the main swimming beach (if a swimming beach exists it is first priority) or the main boat ramp area (if there is no swimming beach, this is the site of

Table 6. Lake and wetland stratification status for the 30 sites surveyed during 1993.

Lake	Date Sampled	Temperature Decline Rate (degrees/meter)	Dissolved Oxygen Decline Rate (mg/L per meter)	Thermocline Depth (meters)
Alma City Lake	July 27	-1.45	-0.69	5-7
Cedar Creek Lake	July 13	-0.81	-0.65	about 5
Cheney Lake	June 2	-0.07	-0.22	none present
Council Grove Lake	June 15	-0.30	-0.54	none present
Cowley Co. SFL	August 2	-1.19	-0.96	6-7
El Dorado Lake	June 2	-0.37	-0.49	none present
Elk Co. SFL	June 21	-2.08	-1.33	3-4
Gardner City Lake	July 28	-1.63	-1.08	3-6
Hillsdale Lake	July 12	-0.46	-0.54	none present
John Redmond Lake	June 14	-0.09	-0.18	none present
Lake Crawford	August 10	-1.11	-0.51	7-9
Lebo City Lake	July 20	-0.57	-0.40	none present
Madison City Lake	August 3	-1.00	-0.97	3-4
Marais des Cyg. WMA	June 10	-2.67	-3.47	0.5-1.5
Marion Lake	June 15	-0.06	-0.24	none present
Marion Co. SFL	July 20	-1.13	-1.01	4-6
McPherson Co. SFL	July 19	-1.14	-0.86	2-3
Melvern Lake	June 14	-0.36	-0.39	none present
Moline City Lake #2	June 21	-1.70	-1.64	about 3
Neosho WMA	June 10	-1.30	-2.20	0.5-1.5
Osage Co. SFL	July 26	-1.30	-0.84	5-7
Pomona Lake	June 14	-0.50	-0.32	6-7
Sedan North City Lk.	June 21	-1.60	-1.12	3-4
Strowbridge Res.	July 26	-0.50	-0.71	none present
Thayer New City Lake	June 22	-2.70	-1.56	about 3
Wabaunsee Co. Lake	July 27	-1.00	-0.51	6-9
Wellington Old Lake	August 2	no profile taken		
Winfield City Lake	August 3	-0.67	-0.59	10-11
Wyandotte Co. Lake	July 28	-1.58	-0.75	5-6
Yates Center Lake	July 15	-1.65	-0.89	5-6

secondary priority). The selection of the boat ramp area as an alternate sampling site was made since it is one of the most likely sites for contact recreation, whether or not facilities exist for swimming. On occasion, samples near fish cleaning stations (third priority for sampling) may be taken for comparative purposes, if no swimming beaches exist.

Table 7 presents the bacterial data collected during the 1993 sampling season. All counts are compared to the 200 colonies/100 mL standard for contact recreation within the Kansas Surface Water Quality Standards (KDHE, 1987; KDHE, 1993).

Seven lakes, out of the 30 surveyed, had fecal coliform bacterial counts that exceeded the 200 colonies/100 mL criteria for contact recreation. The majority of these higher bacterial counts can be attributed to recent influxes of flood water. Thayer New Lake, Sedan North Lake, McPherson County SFL, Lebo Lake, and Marion Lake all appear to have been recovering from those influxes at the time of sampling. In the case of the other two lakes, other factors may have been acting in concert with the flood water inputs. In the case of Strowbridge Reservoir, small feedlots on the inflow streams to the lake may have had a significant influence on lake bacterial quality. At the time of sampling, Alma City Lake had numerous cattle present with direct access to the lake.

Limiting Nutrients and Physical Parameters

The determination of which nutrient, or physical characteristic, "limits" phytoplankton production is of primary importance in lake management. If certain features can be identified, which exert exceptional influence on lake water quality, those features can be addressed in lake protection plans to a greater degree than less important factors. In this way, lake management can be made more efficient.

The concept of limiting nutrients, or limiting factors, is often difficult for the layman to grasp. The following analogy is provided in an attempt to clarify the concept:

> A person is given 10 spoons, 9 knives, and 5 forks. They are then asked to place sets of utensils at each place at a table. Further, only complete sets of utensils are to be placed, with a complete set including all three tools. The question is, "What tool is the limiting factor?"
>
> In this example, the number of forks available "limits" the number of place settings that can be made. Therefore, forks become the limiting factor for this scenario.

In a lake ecosystem, the level of algal production is the "place setting," while plant nutrients and light availability are the "spoons, forks, etc." Common factors that limit algal production in lakes are the levels of available nutrients (primarily phosphorus and nitrogen) and the amount of light available to power photosynthesis. Less common limiting factors in lakes include available levels of carbon, iron, manganese, temperature, and vitamins.

The use of nutrient ratios are commonly employed to estimate which major plant nutrients are limiting factors in lakes. These ratios take into account the relative needs of algae cells for the different chemical nutrients. Typically, total nitrogen/total phosphorus (TN/TP) mass ratios that are above 7.5 indicate phosphorus limitation. Conversely, TN/TP ratios below 7.5 indicate nitrogen limitation. Ratio numbers near 7.5 indicate that both, or neither, of these major plant nutrients may be limiting to phytoplankton production (Wetzel, 1983). The 1992 season marked the first during which total nitrogen data was available to the Lake and Wetland Monitoring Program, thus making the determination of limiting nutrients possible.

Table 8 presents limiting factor determinations for the lakes surveyed during 1993. It should be kept in mind that these determinations reflect the time of sampling and may not apply to other times of the year. Also, the assumption was made that no unusual circumstances or conditions, present at the time of sampling, influenced which nutrient or factor became the limiting one.

As can be seen from the data in Table 8, phosphorus (or phosphorus in combination with light availability) is the primary limiting factor for lakes surveyed during the summer of 1993. Eighteen of the 30 lakes were primarily phosphorus limited, or limited by both phosphorus and light availability. Three lakes were limited primarily by nitrogen, or nitrogen combined with light availability. Another six lakes were limited by a combination of nutrients. Three lakes were identified as limited by both nutrient and light availability.

In Kansas, many lakes are influenced by the amount of light able to penetrate into the lake to power photosynthesis. In addition, this physical factor can change suddenly with storm water inflows or wind. However, despite its possibly intermittent influence, light limitation remains an important feature in the ecology of many lakes. During 1993, six lakes were viewed as primarily light limited, with four more secondarily limited by light availability. Given the inflow of turbid flood water to many of these lakes during the summer of 1993, it is rather surprising that more were not determined to be potentially light limited.

Table 7. Fecal coliform bacterial counts from the 30 lakes and wetlands surveyed during 1993. Since wetlands are not considered "attainable" for contact recreational use, those values are given for informational purposes only. It should also be kept in mind that these are one time grab samples taken during the week, not during the weekends which should be higher use periods. All units are in "number of colonies per 100 mL of lake water."

Lake	Site Location	Fecal Coliform Count
Alma City Lake	boat ramp	385
Cedar Creek Lake	boat ramp	55
Cheney Lake	boat ramp	<57
Council Grove Lake	boat ramp	25
Cowley Co. SFL	boat ramp	40
	fish cleaning station	20
El Dorado Lake	boat ramp	35
Elk Co. SFL	boat ramp	25
Gardner City Lake	boat ramp	40
	private beach	30
Hillsdale Lake	boat ramp	47
John Redmond Lake	boat ramp	25
Lake Crawford	swim beach	<10
Lebo City Lake	boat ramp	350
Madison City Lake	swimming dock	25
Marais des Cygnes WMA	open water	<2
Marion Lake	swim beach	300
Marion Co. SFL	swim beach	60
McPherson Co. SFL	boat ramp	1,050
Melvern Lake	federal swim beach	20
	state swim beach	30
Moline City Lake #2	boat ramp	<80
Neosho WMA	open water	25
Osage Co. SFL	boat ramp	75
Pomona Lake	federal swim beach	50
Sedan North City Lake	boat ramp	280
Strowbridge Reservoir	boat ramp	240
Thayer New City Lake	boat ramp	205
Wabaunsee Co. Lake	swim beach	65
Wellington Old City Lake	boat ramp	<200
Winfield City Lake	swim beach	<100
Wyandotte Co. Lake	boat ramp	150
Yates Center Lake	boat ramp	20
	fish cleaning station	50

Table 8. Limiting factor determinations for the 30 surveyed lakes in 1993, including TN/TP ratios. Factors are listed in descending order of importance.

Lake	TN/TP Ratio	Limiting Factors Present
Alma City Lake	<9	light, nitrogen, phosphorus
Cedar Creek Lake	<16	light, phosphorus
Cheney Lake	8-12	light, phosphorus, nitrogen
Council Grove Lake	9-10	light, phosphorus, nitrogen
Cowley Co. SFL	>10	phosphorus
El Dorado Lake	<20	phosphorus
Elk Co. SFL	>21	phosphorus
Gardner City Lake	8-9	phosphorus, nitrogen
Hillsdale Lake	19	phosphorus
John Redmond Lake	13-17	phosphorus, light
Lake Crawford	15-17	phosphorus
Lebo City Lake	<9	nitrogen, light
Madison City Lake	>10	phosphorus
Marais des Cyg. WMA	14-23	phosphorus
Marion Lake	22-24	phosphorus
Marion Co. SFL	<11	phosphorus, nitrogen
McPherson Co. SFL	<4	light, nitrogen
Melvern Lake	29-39	phosphorus
Moline City Lake #2	12-22	phosphorus
Neosho WMA	18-21	phosphorus, light
Osage Co. SFL	<12	phosphorus, nitrogen
Pomona Lake	18-22	phosphorus
Sedan North City Lake	>26	phosphorus
Strowbridge Res.	14-19	phosphorus, light
Thayer New City Lake	13-14	phosphorus
Wabaunsee Co. Lake	<10	phosphorus, nitrogen
Wellington Old Lake	4-6	light, nitrogen
Winfield City Lake	<18	phosphorus
Wyandotte Co. Lake	<11	phosphorus, nitrogen
Yates Center Lake	10	phosphorus, nitrogen

Surface Water Exceedences of State Water Quality Criteria

All numeric water quality criteria referred to in this section are taken from the proposed revisions to Chapter 28 of the Kansas Administrative Regulations (K.A.R. 28-16-28b through K.A.R. 28-16-28f), or from EPA water quality criteria guidance documents (EPA 1972, 1976; KDHE, 1993). Copies of the Standards may be obtained from the Office of Science and Support, KDHE, Building 740, Forbes Field, Topeka, Kansas 66620.

Tables 9 and 10 present documented exceedences of state surface water quality criteria during the 1993 sampling season. These data were generated by comparison of a computer data retrieval, for 1993 Lake and Wetland Monitoring Program ambient data, to the proposed state surface water quality standards. Only those samples above 3.0 meters depth were used to document standards violations, as a majority of those samples below 3.0 meters are from hypolimnetic waters. In Kansas, lake hypolimnions generally constitute a small percentage of total lake volume and, while usually having a greater number of pollutants present in measurable quantities (compared to surface waters), do not pose a significant water quality problem for the lake as a whole.

Table 9. Chemical parameters exceeding chronic and acute aquatic life support criteria in lakes surveyed during 1993. Chemical symbols are from the Periodic Table of the Elements. Aquatic life support is abbreviated ALS while dissolved oxygen is abbreviated as DO. Only those lakes with some type of documented exceedence are included in Tables 9 and 10.

	Chronic ALS							Acute ALS			
Lake	Cu	Se	Zn	Hg	DO	pH	Atrazine	Cu	Se	Zn	DO
Cedar Creek Lake							x				
Cowley Co. SFL	x	x							x		
El Dorado Lake	x										
Elk Co. SFL	x				x						x
Gardner City Lake	x				x						x
Hillsdale Lake	x						x	x			
Lake Crawford	x	x						x	x		
Lebo City Lake	x						x	x			
Madison City Lake	x							x			
Marais des Cyg. WMA	x					x					
Marion Lake	x										
Marion Co. Lake	x										
McPherson Co. SFL	x		x		x		x	x		x	x
Melvern Lake							x				
Neosho WMA	x			x	x			x			x
Osage Co. SFL	x										
Pomona Lake	x						x	x			
Sedan North Lake	x				x			x			x
Strowbridge Res.	x						x	x			
Thayer New Lake	x										
Wabaunsee Co. Lake	x										
Wellington City Lake	x	x	x					x	x	x	
Wyandotte Co. Lake	x										
Yates Center Lake	x			x				x			

With respect to the aquatic life support use, copper, dissolved oxygen, and atrazine constituted the majority of the exceedances of numeric water quality criteria during 1993. Out of 24 lakes and wetlands with exceedences, 22 exceeded the chronic criteria for copper and 11 exceeded the acute copper criterion. Next, in terms of frequency, were the 10 violations of the dissolved oxygen criterion, followed by the 7 exceedences of the chronic criterion for atrazine. Of much lower frequency were exceedences of the selenium, zinc, mercury, and pH criteria. All pH exceedences were for values above 8.5 standard pH units. In all cases, these high values were due to primary production within the algae and macrophyte communities, not due to outside pollution sources. Likewise, all low dissolved oxygen values were due to the shallow stratification of a few of the surveyed lakes. These shallow stratification situations were due to the existing, site specific, weather conditions during the early summer. They do not represent the effects of outside pollution sources.

Table 10. Exceedences of human use criteria and/or EPA guidelines within the surface waters of the lakes surveyed during 1993. Symbols are taken from the Periodic Table of the Elements. Only lakes with documented exceedences are included within the table. An "x" indicates that the exceedence occurred for a use presently existing at the given lake. An "*" indicates that the exceedence occurred where the indicated use does not presently exist.

Lake	Water Supply Atrazine	Irrigation Zn	Irrigation Se	Human Health Hg
Cedar Creek Lake	x			
Cowley Co. SFL			*	
Lake Crawford			*	
Neosho WMA				x
Wellington City Lk.		*	*	
Yates Center Lake				x

As shown in Table 10, there were relatively few exceedences of surface water quality numeric criteria (not including aquatic life support) during 1993. None of the irrigation exceedences occurred at lakes that serve as sources of irrigation water, and the two mercury detections (under human health) may be due to contamination of the samples. Both values were near the KDHE Laboratories' analytical quantification limit, and the detections did not occur in both of the duplicate surface samples collected at these two sites. Therefore, only the atrazine exceedence for drinking water supply use, at Cedar Creek Lake, may constitute a true violation of numeric criteria under the human use category.

Pesticides in Kansas Lakes, 1993

Twenty lakes had detectable levels of pesticides within the main body of the lake during 1993. Table 11 lists these lakes and the pesticides that were detected, along with the level detected and analytical quantification limit. Three different pesticides were detected in total.

Atrazine continues to be the most often detected pesticide in lakes in Kansas (KDHE, 1991). Atrazine was identified in all twenty lakes with detectable levels of pesticides. Seven lakes had detections of Dual (metolachlor), and four lakes had detections of alachlor. Frequency of detection will appear much greater when comparing 1993 data to previous Lake and Wetland Program reports due to a lower analytical quantification limit for atrazine. The previous "detection" limit for atrazine was 1.2 ug/L. With the 1993 sampling season, the limit dropped to 0.3 ug/L.

In all cases, the detection of these pesticides indicates impacts from agricultural nonpoint source pollution. The site of most concern during 1993 was Cedar Creek Lake. This lake exceeded both the aquatic life support and drinking water supply criteria. It should be kept in mind that 1993 was a flood year, which may have had a profound impact on the data collected during this year. While detections may have increased due to flood runoff (which removed incorporated pesticides from last year's "carry over"), farmers were unable to apply herbicides to many fields during the spring due to the saturated ground. If the spring had been dry enough to allow access to fields, both detection frequencies and herbicide concentrations may have exceeded those reported in previous years.

Discussion of Nonpoint Sources of Pollution for Selected Lakes

Certain lakes and wetlands were chosen for further discussion, based on the number and type of surface water quality standards exceedences that were observed. A waterbody was chosen if 1) three, or more, parameters experienced exceedences of chronic criteria of the aquatic life support use, 2) more than one parameter experienced exceedences of acute criteria of the aquatic life support use, or 3) more than one parameter exceeded irrigation, water supply, livestock watering, or human health criteria.

Based on these considerations, five lakes and wetlands were chosen for further discussion regarding the sources of their use impairments. The five waterbodies identified were Lake Crawford, Wellington City Lake, Sedan North City Lake, McPherson County SFL, and Neosho WMA.

In all five cases, significant flood flows had been received over the course of the growing season. It is likely that these influxes contributed the majority of the use impairments, although some of the metal impairments may have been due to local geology. In virtually all cases, dissolved oxygen impairments were caused because the lake had developed a shallow thermocline early in the summer. This condition reflects weather conditions during the spring and early summer for each given lake.

Table 11. Pesticides detected during 1993 in Kansas lakes. All values are in ug/L. Analytical quantification limits are as follows for the three detected pesticides: atrazine = 0.3 ug/L, dual = 0.25 ug/L, alachlor = 0.1 ug/L. The "exceeded" column refers to whether atrazine concentrations exceeded current EPA aquatic life support (ALS) levels (1.0 ug/L), or the current MCL of 3.0 ug/L for water supply (WS).

Lake	Pesticide			Exceeded	
	Atrazine	Dual	Alachlor	ALS	WS
Cedar Creek Lake	4.50	0.48	-	x	x
Cheney Lake	0.40	-	0.18		
Council Grove Lake	0.43	-	-		
El Dorado Lake	0.52	-	-		
Gardner City Lake	0.78	-	-		
Hillsdale Lake	2.40	0.26	0.19	x	
John Redmond Lake	0.55	-	-		
Lake Crawford	2.20	-	-	x	
Lebo City Lake	1.10	-	-	x	
Madison City Lake	0.50	0.50	-		
Marais des Cyg. WMA	1.00	-	-	x	
Marion Lake	1.50	0.46	-	x	
Marion Co. SFL	0.77	-	-		
McPherson Co. SFL	1.30	-	-	x	
Melvern Lake	1.40	-	0.12	x	
Osage Co. SFL	0.84	0.30	-		
Pomona Lake	2.50	0.72	0.11	x	
Strowbridge Res.	2.80	1.60	-	x	
Wellington Old Lake	0.32	-	-		
Winfield City Lake	0.47	-	-		

Taste and Odor/Algae Bloom Investigations and Other Special Investigations in 1993

During the period of October 1, 1992 to September 30, 1993, six investigations were undertaken within the auspices of the Taste and Odor/Algae Bloom Program. Each will be discussed individually within the remainder of this section. Three of the investigations were related to fishkills, one to taste and odor problems in drinking water, one to aesthetic/pollution concerns, and one to potential algae toxicity.

On May 20, 1993, algae samples from Hargis Creek Lake (Wellington, Kansas, Sumner County) were submitted as part of a fishkill investigation conducted by the KDHE Southcentral District Office. Lake dissolved oxygen was measured at less than 1 mg/L, which was identified as the immediate cause of the fishkill. Algae samples indicated a small amount of planktonic material, but also indicated the presence of abundant green filamentous algae. Past records also indicated that this lake experiences spring fishkills on a regular basis. Local authorities speculated that filamentous algae might be the cause, based on the historical accounts. Based on the data available, it was concluded that the fishkills were induced either by die-off of excessive filamentous algae or by diel variations in dissolved oxygen levels associated with the filamentous algae.

On June 21, 1993, algae samples were submitted from the KDHE Southcentral District Office from a fishkill investigation near Colwich, Kansas (Sedgwick County). The fishkill occurred in a series of small ponds. All the ponds were reported to have greater than 15 mg/L dissolved oxygen, which is at, or near, saturation. The algae community was very large (300,000 to 350,000 cells/mL) and composed of a diverse green, diatom, and euglenoid assemblage. As the samples were all collected in the late afternoon, large diel oxygen changes were postulated as the cause of the fishkill. Owing to the metabolic attributes of the algal community, pre-dawn oxygen concentrations could have been very low, while late afternoon oxygen levels exceeded the minimum requirements for fish.

On June 23, 1993, algae samples were submitted from a fishkill at a private pond within the City of Wichita (Sedgwick County). Dissolved oxygen was measured at 3.0 mg/L three days after the kill occurred, and the pond was described as septic in odor and appearance. The algae community samples contained 3-3.5 X 10^6 cells/mL, which is near the maximum recorded by KDHE. The community was composed mainly of the blue-green alga Aphanizomenon flos-aqua, although the blue-green alga Microcystis aeruginosa was also present. Given the pond owner's observations that larger fish were dead, while smaller ones were all gasping at the surface, it was hypothesized that algal toxins were probably not the immediate cause of the fishkill. The likely cause was the deoxygenation of the pond caused by the die-off of this algae community.

On August 25, 1993, a water sample was brought in by an employee of Osage County. The conditions of a small stream, passing through Osage City, had prompted complaints from several citizens. The stream appeared stagnant, had surface scums, and an orange coating on the substrate. The coating was later found to be mainly on exposed plant roots in the stream channel. Microscopic examination revealed no algae community of consequence. However, chemical analysis revealed that the orange coating was extremely rich in iron. Given the amounts and composition of land uses within the stream's watershed, it was determined that the stream suffered from naturally stagnant conditions, with the surface scums due to materials leached from decomposing vegetation in the channel. The iron rich, orange coating was likely due to dissolved iron being oxidized on the plant roots as a result of their metabolic processes.

On September 9, 1993, algae samples from Cheney Lake (Reno County) were submitted by KDHE Southcentral District Office staff. The samples were in response to taste and odor problems in the City of Wichita's water, which is derived from Cheney Lake in part. All samples indicated a moderately sized algae community. The taste and odor producing alga Microcystis aeruginosa represented more than 50% of the community. These algae samples indicated a continuation of the taste and odor problems experienced by Wichita in recent years.

On September 10, 1993, algae samples were collected by KDHE Southcentral District Office staff from a private pond near Garden Plain, Kansas (Sedgwick County). The problem reported was that several dogs had entered the pond over the summer and later developed severe symptoms. These symptoms included complete hair loss, large welts on the body with a red coloration, vomiting, and diarrhea. Three to four weeks earlier, several dead grass carp (Ctenopharyngodon idella) had been noticed in the pond. Algae samples contained small to moderate algae communities, of very diverse composition. Also in the samples were significant numbers of protozoans, fungal spores, and organic debris. The pond was also reported to have had a near 100% duckweed (Lemna spp.) cover for a good portion of the summer. The afflicted dogs had all recovered after veterinary treatment. It was suggested that the dogs probably contracted an illness (bacterial, fungal, etc.) that was able to flourish under the duckweed cover. Ponds with a complete plant cover often become anoxic, allowing many bacteria to flourish that would not otherwise be able to survive. District Office staff advised the owner to keep the dogs out of the pond during, or after, episodes of dense duckweed cover.

CONCLUSIONS

The following conclusions are offered, based upon the lake monitoring data obtained during 1993.

1. Trophic state conditions suggested that most lakes surveyed in 1993 were either constant or degrading in terms of trophic state condition. Flood impacts may have influenced the 1993 sampling data, however.

2. Exceedences of surface water quality criteria revolved primarily around two parameters. These were copper (exceedences of aquatic life support criteria) and atrazine (exceedences of aquatic life support or drinking water supply criteria). Any connection between these exceedences and the use of copper sulphate for algae control in water supply lakes was masked by the ubiquitous nature of copper detections. Twenty-two lakes and wetlands (73% of total sites surveyed in 1993) experienced exceedences of the copper criteria.

3. Twenty of the 30 surveyed lakes (67% of the total) had detectable concentrations of agricultural pesticides during the summer of 1993. Atrazine was the most commonly encountered pesticide. Most of these lakes were within the Marais des Cygnes and Neosho river basins of eastern Kansas, but most lakes sampled during 1993 tended to be located in the southeastern region of the state (Figure 1).

4. The impact of the 1993 flood on lake water quality will likely be very transitory. Most smaller lakes appeared to have received the flood inflows as surface plumes, with no disruption of thermal stratification. Therefore, most of the material contained within the flood waters probably passed through these smaller lakes, although some material and debris will have settled to the lake sediments. The long-term impact of the 1993 flood on the water quality of larger reservoirs is less clear, but likely will be similar to the impact on smaller lakes.

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LAKE DATA AVAILABILITY

Lake data are available for all lakes included in the Kansas Lake and Wetland Monitoring Program. Water quality data may be requested by writing to the Office of Science and Support, KDHE, Building 740, Forbes Field, Topeka, Kansas 66620-0001. All data referenced within this report are also accessible on STORET.